Bologna Process versus Global Engineer Education

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Abstract - **The Bologna process is considered a major revolution in European Higher Education. It has motivated alterations, within the higher education institutions, in the structure of degrees, in curriculum, in duration and in teaching/learning relationships. It has also affected other sectors of society including the financing of the studies. The main features are the creation of three cycles for higher education and other actions to create a more homogeneous set of qualifications within the European education space. These modifications have been decided by each national government in cooperation with the other signatories. In this paper some of the developments of the transformations of engineering education degrees in Europe are presented and discussed. The relationship between the educational changes and the influence in the globalization of engineering education is analyzed. The comparison between these advancements is compared with other developments in other parts of the world concerning the major influences on the effects within the Bologna process countries and with the rest of the world.**

Index - Bologna process, globalization, educational changes, quality assurance, mobility, outsourcing and accreditation.

CURRENT ISSUES IN HIGHER EDUCATION

The engineering education and training systems have been under constant modifications in the recent periods. It is a phenomenon that can not easily be explained by a single reason but it is the sector in the higher education sector that has more activities and debates about education. It is a characteristic that has no comparison in other sectors like Law or Medicine. There are several engineering educational societies that have an intense activity in terms of conferences, workshops, meetings, seminars and public events.

These associations and organizations have a national, regional or continental area of influence. Currently, and under the leadership of the American Society of Engineering Education, ASEE, there is the intent of creating a world federation of the major associations and organizations involved in engineering education. It will have its foundation meeting in Brasil, in October 2006 and will be called IFEES - International Federation of Engineering Education Societies. This is a movement that reflects the interest in having a global interest in discussing the engineering education issues at a global level. It is a situation that has no parallel in any other educational sector and supersedes the volume of activities even in the educational sciences area. It is probably related with the characteristics of engineering where solutions are sought and the fact that engineering education places so many unanswered questions.

Of course this situation with engineering has taken this path of gregarious behaviour but there are other current issues that affect higher education in general. For instance, the cost of public education has risen in the last decades due to the facilitation of access, thus increasing the number of students and to the increase in quality of the education provided, due to the control systems implemented and to the corrective measures. The financing of the increasing higher education has to face challenges that result from the diversification of public funding and with the demanding accountability of the educational funds.

The European Union has been increasing the attention and the political motivation to invest in education and training to transform the group of nations into a internal common space in educational terms without barriers. It has also been trying to attract students and researchers from other parts of the world. The main consequences that have caused some turmoil in Europe are the movement towards the harmonization of degrees, created by the Bologna process, the need for continuing professional development, the tendency for increased mobility of professionals and the lack of accepted global quality assurance of the education and training [1].

The issues the higher education area will have to deal with various challenges like changes in the curriculum, adaptations of teaching/learning methods, implementation of systems directed recognition of qualifications (academic and professional), development of global accreditation schemes, provision for continuing professional development and valuing informal acquisition of competencies and knowledge.

MODIFICATIONS IN EUROPE

I. Bologna Declaration

The biggest change in the recent years in Europe has been the tentative to harmonize the higher education degrees that were initiated by the Sorbonne declaration of May 2000 signed by the four biggest countries of the European Union: France, Germany, United Kingdom and Italy. The respective ministers of education agreed to harmonize their higher education systems to have only three comparable degrees in the higher education system. The first degree should have the duration between three and four years, followed by a second that would award a master degree and a third one that would give the title of doctor. One year later, twenty-five other countries of the European Union and under the support of the European

Commission agreed with the four previous ones to sign the Bologna declaration. This famous declaration aimed at converging reforms "towards a coherent, compatible and competitive European higher education area" [2].

The Sorbonne Declaration aimed for the harmonisation of qualifications of the higher education structure in order to make them readable and facilitate their recognition both within Europe and world-wide. The Bologna declaration confirmed the objective of establishing a clear and operational way for the introduction of an undergraduate-postgraduate articulation of qualifications. It also prescribed the introduction of credit systems in each country compatible within Europe (European Credit Transfer System). The declaration also called for the introduction and development of European co-operation in quality assurance with a view to developing comparable criteria and methodologies [3]. Some European organizations related with engineering education have analyzed the consequences and developments influenced by the declaration. Some position papers were produced and distributed throughout the engineering community, especially in the educational sector. These texts illustrated the preoccupations of the engineering education sector with the implementation of the Bologna process in the engineering area.

II. Mutual Recognition

The existing developments in the signatories of the Bologna declaration towards reforming the engineering degree systems have been very diverse. Some countries have introduced profound reforms and others have not done practically any changes. The majority of the countries have taken this wave of change to introduce other changes that are not directly related with the Bologna process. The relevant one is the reduction of financing in countries where there existed long cycles for engineering basic education. In fact with the creation of short cycles some governments took these alterations to decrease the total funding for engineering education based on the fact that the first cycle would be enough in terms of required engineering education. Another direct consequence among the engineering academic community is the awareness that the curricula and programs of these short cycles of education may be subject to doubts and uncertainties about the respective suitability for the engineering profession and for the competition in the European space. All these transformations have started a path for some form of quality assurance in the engineering area to guarantee the recognition and acceptance of other countries engineering degrees.

Another aspect that has imposed debates about the quality of the engineering programs has been the changes occurred in the paradigm of teaching versus learning. The engineering programs have adopted a system based in the outputs assessment of the engineering graduates like competences and skills [4]. This is a significant change of the traditional educational schemes based on the hours of classes for each discipline of defined areas of knowledge. These areas and respective disciplines were defined almost uniformly among the engineering curricula and the hours of classes were considered the common references among the engineering community, academic and professional.

Since the learning outcomes criteria are new in the assessment of the engineering curricula the engineering professionals and academics have been debating and implementing original forms of quality evaluation of the engineering programs suited for the curriculum development systems based on learning outcomes. Another aspect that needs further research and quality control is the evaluation of the credits for each discipline based on the student workload. It is not easy to measure the hours that a student spends on each module since there is no data available on how the students spend their time working towards their degrees. Another dimension of this difficulty is the random rate of learning by each individual that must allow a large sample of examples. These facts bring a certain degree of uncertainty to the ECTS system for the recognition and the work done in other schools.

In fact the issue of acceptance of the credits obtained in other schools and nations is a crucial one to establish the common European Higher Education area. It is also a cultural issue since there is mistrust and lack of knowledge about other engineering educational systems. The creation of accepted and comparable rules for measuring the student workload and to guarantee minimum quality requirements of the engineering degrees is essential to abolish the invisible walls between engineering schools. It is a fact that is being addressed in Europe but surely necessary in other parts of the world if cooperation and the exchange of engineering students is an objective. It is a cultural question that can be addressed through adequate information systems and training.

III. Mobility and Outsourcing

In Europe, as well as towards the rest of the world, the modern engineer encounters problems when it comes to mobility and employability. When it comes to mobility, one can talk about it from the view of the prospective engineer, of the current engineer and of the prospective employer. For the current engineer it is a matter of the very build-up of the exact curriculum. The aim of these engineering courses is to be flexible about parts of the study programmes achieved at other higher education institutions and to transfer those between curricula. The active engineer wants to have the chance to look for other job opportunities in other countries. The engineer needs some form of recognition of his qualifications obtained through formal education and as a result of the professional experience obtained on the job. Also the professional engineering organizations and employers need to recognize the qualifications and competencies from engineers coming from other countries and, in some cases, from the country where the employer is located. The transformations occurred in the engineering education during the last years has brought to the industry sector some lack of knowledge and a certain mistrust about what are the competences and skills of the recent graduates.

The European Union has devised a scheme for the higher education graduates that tries to address the questions referred. It is called the diploma supplement and it is intended to

complement the information about the degree obtained. It was adopted by all signatories of the Bologna process and it consists of information about the studies performed by the student. The diploma supplement contains data about the competences and skills acquired, about the learning outcomes of the disciplines, about the activities performed during the studies and about the professional employments compatible with the degree. The diploma supplement is intended to facilitate the understanding of the studies performed and therefore facilitate the employment. A similar measure has been established for the continuing professional development and it is compared to a passport. It is a document that is personal, with photo identification and other individual data where all activities that contributed to the continuing education are registered. This professional passport will allow the recognition of the educational enrichment of each professional and promote the valorisation of the acquired competences, skills and knowledge.

In terms of the trends about engineering demography there is a shortage of engineers in the European Union and in other developed regions of the world. The technology requirements and the demographic tendencies have created a significant shortage of engineering graduates. On the other hand, in other parts of the world, engineering is still an attractive career and without shortage of candidates. Arising from this asymmetry between demand and offer two things will happen in the near future. One is the migration of skilled workers, like engineers, with the corresponding problems of recognition of qualifications. The second effect will be the outsourcing of engineering done at continental level. That is already happening with some airline companies that perform their engineering maintenance in other continents. Global engineering is a trend with strong impact in the profession future.

To address this unbalance of engineers the World Trade Organization is currently looking for a regulation of the engineering qualifications at the world level. Some nations in certain regions of the world have made agreements to facilitate recognition and acceptance of the engineers, recent or active, between the different countries. The most known examples of this tendency are the Washington Accord, the Engineers Mobility Forum, the Dublin Accord, the Asian Pacific Economic Cooperation (APEC) Engineer and the Sydney Accord. These are professional engineering agreements but are directly linked to the type of engineering education provided. The APEC Engineer also contemplates the frames for continuing professional development of the engineers in terms of formal and informal training required periodically to maintain the practising licence.

IV. Continuing Engineering Education

The developments in the engineering profession and activities have created the need for suitable training programs compatible with the needs of the professional development. This has created a series of diverse providers of continuing education and of types of courses. This diversity has implied a difficulty in establishing standards and quality assurance mechanisms. The types of providers have varied from higher education institutions to private companies that have their business directed at providing training for engineers. A great share of the continuing education given to engineers is the provision of the employers. The engineering companies define the strategies in terms of training and organize the continuing education activities of the engineers as in house courses.

These different types of engineering programs represent high investments for companies and for engineers. There are no worldwide accepted standards and guidelines although there are quality assurance and recognition schemes for certain areas either academic or geographic. These are reasons that lead to the need for recognition of work done or knowledge acquired by the participants in the continuing education programs. It is not an easy area since the diversity of providers, of forms of training and of the courses format creates a large spectrum to be analysed. Some strategies to promote the quality of continuing education for engineers has been based on the transparency and recognition of the activities undertaken by the employers. Another reason that does not promote the regulation of the activity has been the idea that the competitiveness of the engineers and employers depend on the quality of the training and therefore all major actors will perform as regulators of the market.

OPEN QUESTIONS

I. Basic Engineering Education

The goal of initial education of engineers has been changing in the last years due to the factors cited above. The modern courses have a tendency to adopt a philosophy of ensuring that the graduating engineer will have some acquired competences and skills at graduation. These should be defined by a synthesis of opinions from academics, professionals and employers. These debates between the major players in this filed should make the conciliation between the different aspirations for the graduates. As mentioned, the engineering courses were based on the content and on the contact hours. Currently they tend to be defined by the learning objectives and by the learner workload. This is a shift of paradigm and that leads to major changes in the form and content of courses.

There are recent studies that show the type of competences and skills required for an engineer to work as a professional. For instance from the point of view of professionals some organizations require that the educational outcomes include ability to: apply knowledge of mathematics, science and engineering; design and conduct experiments; design a system, component or process to meet desired needs; function in multidisciplinary teams; identify, formulate and solve engineering problems; understand professional and ethical responsibility; communicate effectively; understand the impact of engineering solutions in a global and societal context; recognize the need and engage in lifelong learning; have a knowledge of contemporary issues; use techniques, skills and modern engineering tools necessary for engineering practice.

In terms of contents it is required by academics that engineers have a combination of mathematics and basic sciences of about one fourth of the workload, a set of disciplines of engineering sciences that establish the bridge to engineering design of about another fourth and a group of engineering design activities related with the specific filed of study. It is desirable that students have a complement of general education courses. Employers have different, but somehow similar, interests in the learning outcomes of the courses like ability to solve problems, self-sufficiency, foreign language skills, capacity to work in teams, critical thinking, practical experience, creativity, etc.. The expected outcomes of the courses taken are different from these perspectives and, in certain cases, although with similar denominations but different meanings. It is the result of the amalgam of these expectations that the profiles of engineering programs for initial education will be defined.

II. Importance of Engineering

It is noted that there are reduced numbers of applicants in the engineering disciplines. This is an issue that is critical and must be solved together by universities and industry. There is a decrease of population that has been affecting the enrolment but another factor has been a lack of interest in the engineering profession by society in general. There is a devaluation of the social benefits of this profession with a corresponding decrease in material compensation. This has diminished the image of engineers in the eyes of prospective engineering students. In fact the difficulties in obtaining success with the basic disciplines of engineering, mathematics and physics, among the prospective engineering students in high school are a major obstacle. One of the motivations for these students could be the acknowledgement that life would be impossible without engineering.

Therefore, efforts have to be made showing the importance of the engineering activities to the public in general, there should be a dissemination of engineering profiles among high school students and there should be more investment in salaries for engineers. In fact engineering is a skilled and responsible activity with a high social value that has not been considered relevant for development and social stability. Engineering education is important to society and to development and the fact that the developed countries have successful engineering educational systems may not be an accident. It is certainly a necessary condition but not a sufficient condition for development. The globalization of engineering education, either through outsourcing or through distance education, will certainly benefit the world development and progress.

III. Continuing Professional Development

The issue of providing continuing professional development (CPD) is critical for engineers [5]. It is an area where the obsolescence of knowledge is intense and the tendency is to have more demands for training courses. The current offer is made by professional organizations, private providers, universities and corporations. These actions take several formats like postgraduate studies, weekend seminars, short courses, in house training, online studies and self learning activities. In certain cases the requirements for these lifelong learning activities are voluntary, others are mandatory and some are recommended. Corporations and professional bodies have a large importance in the provision of CPD activities in the areas of promotion and provision. The CPD activities are not mandatory in most countries and it is done on a random basis without the benefit of more abridging strategies.

Since CPD is a factor of competitiveness it should be considered as a component of the engineering profession with clear frameworks. The universities should play a larger role in the provision of CPD and in the quality assurance of the programs delivered. Mandatory periodic CPD should be applied by all professional engineering organizations. The quality of engineering in general depends on the maintenance of proper competences and skills that have a technical nature but also have a social component. Issues like ethics, citizenship and social engagement should be topics for engineers CPD. Engineering educators should also take CPD courses to keep their level of teaching adapted to the continuous changes of the educational practices and techniques.

IV. Quality Control and Assurance

It is clear that there are great differences between the European countries when it comes to determining and assuring quality of higher education. In some countries accreditation is already in place by means of departmental order, nationally recognised agencies or others. Facing these differences it is necessary to find the minimum common standard for quality assurance. Probably the starting point will be to trust national quality assurance systems [6]. It is not the aim of the international accreditation system to verify the fulfilling of the goals set by the higher education institution. It is a question of the institution pursuing these goals established as minimum standards to ensure quality.

It is generally agreed on that a bottom-up approach is the one and only way to establish recognition of qualifications on an international level. In order to establish such an approach it is required to find the minimum standards in common and thus find the common qualification attributes desired. The main issue big about the outputs assessment is to find an accurate way to evaluate the criteria. The proposed approach focuses on the outcome of the educational process and not on its inputs, which are more tangible and measurable.

Accreditation of the courses has therefore become an inevitable activity for the academic institutions and for the engineering professional organizations. The issues considered essential are the protection of engineering profession, the mobility and transparency, the compatibility and improvement. A good example is the project EUR-ACE (European Accredited Engineer) that congregates most European organization related with engineering education or with professional organizations [7].

Accreditation of engineering activities have been analysed considering the classical degrees like bachelor, master or doctorate. The question of continuing professional development activities has been recently addressed due to the increasing importance of the lifelong learning in engineering. These activities become more difficult to recognize when taking the format of distance learning or of e-learning. A good example is the recognition of informal learning that may attract individuals to continue their studies in engineering [8]. This could contribute to enlarge the number of qualified elements in engineering and could help increasing the level of qualifications of the sector.

V. New Publics in Engineering

This is a relatively new area where experiential learning can be credited towards a qualification. AIPL (Accreditation of Informal and Prior Learning) seeks to give credit for all learning by placing it within a recognised accreditation framework. It involves the identification of learning wherever and whenever it takes place, selection of that learning which is relevant to a desired outcome or progression route, demonstration of the validity of and appropriateness of that learning, matching learning outcomes to those stated within a chosen accreditation or progression framework, assessment of evidence against predetermined criteria to ensure the validity of the claimed competence and accreditation within an appropriate accreditation framework.

The relevant methodologies proposed for accreditation of AIPL are based on performance evidence and knowledge evidence. These evidences are connected with credit units that can quantify the embedment in a framework system enabling a formal partial or total recognition within a qualification framework. This qualification can lead to a degree or to a level of professional recognition. The board in charge of the analysis of the historical evidence and of other proofs of learning should look into authenticity, directness, breadth and currency. The approaches based on the workload and on competency-based systems require qualifications to have clear learning outcomes, levels and progression built into them. The learning outcomes act as the basis for the assessment of AIPL and any subsequent award of credits. Different methods exist for this accreditation process including the use of accreditation boards, portfolio presentation or just taking examinations.

CONCLUSIONS

The perspectives for Engineering Education and Profession in Europe are challenging and promising. The focus recently being made on the Bologna process just postpones other aspects that are probably more significant than those directly related with the Bologna process. It is a fact, according to the survey of the implementation of the Bologna process made by SEFI [9], that other subjects related with engineering education and profession have been included in the discussion. Bologna has the merit of promoting change and, therefore, giving opportunity for other improvements. The system of three degrees has been generally implemented, the ECTS is active on most universities, some countries and universities have adopted the diploma supplement. It is a process that will be generally implemented with several degrees of accomplishments.

There are issues that should be discussed besides those stated in detail previously that arise from the Bologna process and from the Bergen communiqué issued by the Ministers of Education of the Bologna process. The question of evaluating the European credits, the financing of the higher education, the structural reforms of the quality and accreditation systems, the transformation of PhD studies into a profession, the attractiveness for foreign students, the qualification of the active engineers are probably the questions without answers for Engineers. These are intensively related with the characteristics of the profile of this profession with relevance to the responsibilities assumed in civil, social and legal terms. It is necessary more debates and decisions that may, to a certain extent, be different from other engineering areas.

The European experience may not be a complete and perfect example but surely has some advantages and adequate procedures that may be used in other circumstances and environments. The need for communication and exchange of information between the engineering education communities around the world is needed for the reasons presented. Engineering needs more the knowledge about what is happening in other corners of the globe than improving the quality of the graduates. In general the quality of the engineers is, as minimum standard, appropriate due to the constant preoccupation of the engineering educators concerning the quality of the teaching and learning provided. The creation of IFEES - International Federation of Engineering Education Societies may be a decisive measure to transform the engineering education in a global common good that may contribute effectively to a global world with less poverty, more development and increased confidence in the future.

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